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SPECIAL ARTICLE

The usefulness of an earphone-type infrared tympanic thermometer during cardiac surgery with cardiopulmonary bypass: clinical report

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Abstract We evaluated the usefulness of a novel earphone-type infrared tympanic thermometer (IRT) during cardiac surgery with cardiopulmonary bypass. Tympanic membrane temperature (T_{Tym}) was monitored using the IRT inserted into the right ear canal of 12 adult patients (ASA III) who had been scheduled for elective cardiac surgery with cardiopulmonary bypass under general anesthesia. Rectum (T_{Rec}) and nasopharyngeal temperatures (T_{Naso}) were also monitored, and all temperatures were recorded at 5-min intervals during cardiopulmonary bypass. Operating room temperature was kept at 20°–27°C; a conductive warming/cooling system was used to control the patient's body temperature. Of 265 measurements obtained, body temperature range was 31.6°–37.6°C. No complications were related to site of insertion of the monitoring probe. Significant correlations were seen between T_{Tym} and T_{Naso} ($r = 0.971$, $P < 0.001$), and T_{Tym} and T_{Rec} ($r = 0.759$, $P < 0.001$). A Bland–Altman plot showed that average temperature of T_{Tym} was 0.06°C above T_{Naso} (±0.66°C, 2 SD) and 0.12°C below T_{Rec} (±1.78°C, 2 SD). We conclude that an earphone-type IRT is noninvasive and hygienic and could continuously evaluate selective cerebral temperature during cardiopulmonary bypass in adults.

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Body temperature is one of the most important monitoring needs to avoid brain damage or cardiac ischemia during cardiac surgery [1, 2]. Although core temperature during cardiac surgery is usually monitored in the pulmonary artery, rectum, and bladder, specific cerebral temperature monitoring is sometimes required to evaluate cerebral circulation during cardiopulmonary bypass (CPB) [3]. We previously reported the accuracy and usefulness of an infrared tympanic thermometer (IRT) [4]. Recently, Kiya et al. [5] demonstrated that tympanic membrane temperature (T_{Tym}) using a novel earphone-type IRT is suitable for continuous core temperature monitoring during CPB because of its clinically acceptable limits, compared to esophageal temperature, and its noninvasive and hygienic manner. In this study, we evaluated the properties of this earphone-type IRT for core temperature monitoring during CPB in cardiac surgery compared to rectal (T_{Rec}) and nasopharyngeal temperature (T_{Naso}).

The institutional review board at the Faculty of Medicine, University of Yamanashi, approved this trial, and written informed consent was obtained from each patient. Patients who had nasopharyngeal, anal, or ear canal diseases were excluded from the study. Twelve adult patients who had been scheduled for elective cardiac surgery with CPB were enrolled in this study. Before induction of anesthesia, the probe of the earphone-type IRT (CE Thermo; Nipro, Tokyo, Japan) was inserted into the right ear canal. General anesthesia was induced with propofol (target controlled infusion, 2–3 µg/ml), remifentanil (0.15–0.5 µg/kg/min), and fentanyl (1–4 µg/kg). The trachea was intubated with 0.6–0.9 mg/kg rocuronium. Anesthesia was maintained with continuous infusion of propofol and remifentanil, intermittent administration of fentanyl (total, 10–30 μg/kg), and 0.5–2.0% sevoflurane in oxygen. Thermistor probes were inserted into the rectum (approximately 8 cm) and nasopharynx (approximately the distance from external acoustic foramen to nostril) to measure T_{Rec} and T_{Naso}, respectively. T_{Tym}, T_{Rec}, and T_{Naso} were continuously monitored and recorded at 5-min intervals during CPB. Operating room temperature was 20°–27°C, and a conductive warming/cooling system (Medi-Therm III; Gaymar Industries, Buffalo, NY, USA) was used to control the patient's body temperature. A power analysis indicated that 9 patients were sufficient to detect coefficient of correlation $r = 0.85$ with alpha = 0.05 and a power of 0.8. The T_{Tym} was evaluated in comparison with T_{Naso} or T_{Rec} as a body core temperature. Bland–Altman plots were also used to evaluate the limits of agreement. The mean value of the difference (=bias) was >0.4°C, and 2 standard deviations (SD) >±1.0°C was considered clinically significant [6].

We enrolled 12 patients aged 48–92 years (mean, 67 years). Median body weight was 56 kg (range, 30–74 kg), and median body height was 156 cm (range, 131–177 cm). Median operation duration was 264 min (range, 187–331 min) with a median duration of CPB of 116 min (range, 88–159 min). A total of 265 measurements were obtained for each body temperature. Temperatures evaluated in the calculations ranged from 31.6° to 37.6°C. There were no complications related to site of insertion of monitoring probe. Significant correlation occurred between T_{Tym} and T_{Naso} ($r = 0.971$, $P < 0.001$), and the correlation coefficient was higher than that between T_{Tym} and T_{Rec} ($r = 0.759$, $P < 0.001$) (Fig. 1). The Bland–Altman plot showed that the average temperature of T_{Tym} was 0.06°C above T_{Naso} (±0.66°C, 2 SD), and 0.12°C below T_{Rec} (±1.78°C, 2 SD) (Fig. 2). This evaluation indicated that T_{Tym} could be accepted to replace T_{Naso}.

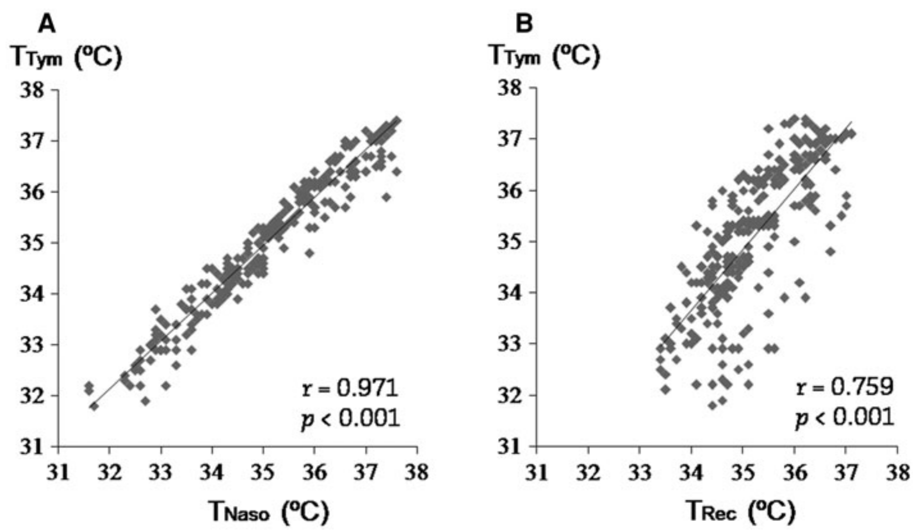

Fig. 1 Correlation analysis between tympanic (T_{Tym}) and nasopharyngeal (T_{Naso}) temperatures (**a**) and between tympanic and rectal temperatures (T_{Rec}) (**b**) in cardiac surgery with cardiopulmonary bypass. There was significant correlation between T_{Tym} and T_{Naso} ($r = 0.971$, $P < 0.001$), and the correlation coefficient was higher than that between T_{Tym} and T_{Rec} ($r = 0.759$, $P < 0.001$)

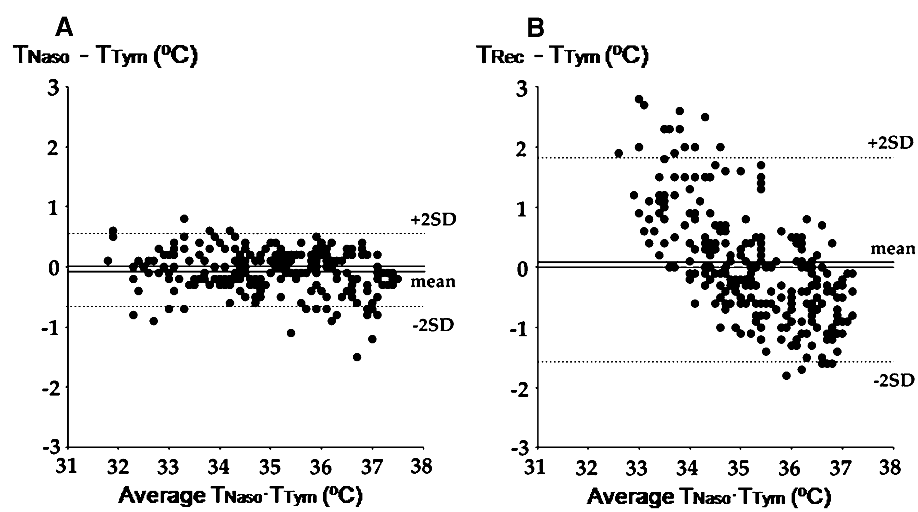

Fig. 2 Bland–Altman analysis between tympanic (T_{Tym}) and nasopharyngeal temperatures (T_{Naso}) (**a**) and between tympanic and rectal temperatures (T_{Rec}) (**b**) in cardiac surgery with cardiopulmonary bypass. Average temperature measured with the infrared tympanic thermometer was 0.06°C above the T_{Naso} (±0.66°C, 2 SD). Bias and repeatability between T_{Tym} and T_{Naso} were <0.1°C and <0.6°C, respectively. The average temperature measured with the infrared tympanic thermometer was 0.12°C below the T_{Rec} (±1.78°C)

In this study, we showed that temperature measurements using the earphone-type IRT are reliable for core temperature monitoring during CPB in cardiac surgery, and T_{Tym} and T_{Naso} had a higher correlation than T_{Tym} and T_{Rec}. It is widely known that measurement of T_{Tym} is a useful method for core temperature monitoring during noncardiac surgery [4, 5], CPB [5], intensive care [7], and therapeutic hypothermia [7]. Because of the direct blood supply from the carotid artery to the tympanic membrane, T_{Tym} has a high correlation to core temperature and can accurately follow body temperature [8]. However, T_{Tym} is commonly monitored by a contact-type device that sometimes causes pain in the tympanic membrane in conscious patients. Tympanic membrane damage caused by insertion of a device has been reported [9, 10]. In this study, a disposable, noncontact-type device allowed continuous temperature monitoring. Patients can set the device comfortably by themselves, the same as inserting a music earphone. By using an appropriate algorithm, this device enables continuous measurement of infrared rays at 1-s intervals with no drift in measured values.

Hypothermia during CPB is performed for brain protection during cardiac or neurosurgery. Deep hypothermia, selective cerebral perfusion, and elective circulatory arrest are also applied for further cerebral protection. Accurate cerebral temperature management to avoid undercooling or overheating during CPB is a major concern during cardiovascular surgery [3]. In this study, the range of alteration of T_{Rec} during CPB was smaller than that of T_{Naso} or T_{Tym}, by head temperature monitor. Cerebral temperature would change rapidly compared to rectal temperature because of cerebral perfusion. The adequate temperature monitoring sites provide optimal estimation of intracerebral temperature [11]. T_{Naso} reflects the carotid artery temperature, and is one of the most optimal surrogates of cerebral temperature because of the easy access and limited risk [12]. However, monitoring T_{Naso} is unable to estimate left and right carotid artery temperature separately. Temperature monitoring at the jugular venous bulb, which receives 99% of cerebral venous blood flow, is considered to directly monitor cerebral circulation and can selectively estimate right and left cerebral temperature [13]. However, this method is very invasive, and it cannot be more than cerebral temperature with inaccurate positioning of the jugular venous bulb catheter or in patients with head injuries [14]. This study proved that T_{Tym} is a reliable device for continuous core temperature monitoring by its clinically acceptable limits and noninvasive and hygienic manner. Monitoring T_{Tym} with this device has the possibility to estimate left and right cerebral temperature separately during CPB in aortic arch replacement. Thus, T_{Tym} with IRT is the most optimal monitor for cerebral perfusion temperature during CPB.

Further studies are needed to show the utility of the IRT more significantly. At first, the core temperature in a pediatric patient is easily changed by surface cooling and warming. However, we did not have pediatric data of T_{Tym} during CPB. Peripheral cooling has been widely performed for cerebral protection during pediatric cardiac surgery. It is reported that T_{Tym} is affected by environmental airflow or head cooling treatment [15]. Influence of head cooling on T_{Tym} should be studied to estimate the utility of the IRT. Second, bilateral side T_{Tym} monitoring using this device during selective cerebral perfusion should be estimated. Selective monitoring of T_{Tym} is important during aortic arch replacement, and the validity of the T_{Tym} should be compared with regional cerebral oximetry using the near-infrared spectroscopy technique.

In summary, correlation and Bland–Altman analysis of the temperature data suggested that an earphone-type IRT is noninvasive, hygienic, and suitable for continuous cerebral temperature monitoring during cardiac surgery with CPB in adults.

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